Report No. RD-65-10

FINAL REPORT

Project No. 242-006-03X

UAL/FAA ATC RADAR BEACON ALTITUDE REPORTING TEST

JANUARY 1965

FEDERAL AVIATION AGENCY

Systems Research & Development Service

Atlantic City, New Jersey

FINAL REPORT

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JANUARY 1965

This report has been approved for general availability. It does not necessarily reflect FAA policy in all respects and it does not, in itself, constitute a standard, specification, or regulation.

for - James W. Mollenauer
Joseph D. Blatt, Director
Systems Research and
Development Service
Federal Aviation Agency

Experimentation Division
National Aviation Facilities Experimental Center
Atlantic City, New Jersey

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

APPENDIX

Federal Aviation Agency, Systems Research and Development Service, National Aviation Facilities Experimental Center, Experimentation Division, Atlantic City, N. J.
UAL/FAA ATC RADAR BEACON ALTITUDE REPORTING TEST by Felix F. Hierbaum, Jr. and Carlo Yulo, Final Report, January 1965, 24 pp., incl. illus., plus 3 appendixes
(Project No. 242-006-03X, Report No. RD-65-10)

ABSTRACT

The National Aviation Facilities Experimental Center monitored 186 flights of 25 different United Air Lines Boeing 727 aircraft and 17 flights of three different Douglas DC-8F aircraft, all equipped with Air Traffic Control Radar Beacon System (ATCRBS) automatic altitude reporting capability.

The participating aircraft were equipped with two different types of automatic altitude reporting configurations, and two different types of ground decoding and display systems were used. Information was gathered on adequacy of the ATCRBS pressure altitude transmission medium, the technical integrity of the two specific decoding and display systems, and correspondence between the pilot altitude display in the cockpit and the radar beacon altitude display at the ground facility.

The data analyzed and controller comments on data received are included along with review notes.

PURPOSE

The purpose of this effort was to obtain information on correspondence between altitude information displayed to and used by the pilot and the automatically reported altitude data transmitted by the Air Traffic Control Radar Beacon System automatic altitude reporting feature. In addition to the correspondence data, observations were made of normal altitude fluctuations as seen by the ground controllers. Information was also gathered on the adequacy of the Air Traffic Control Radar Beacon System pressure altitude transmission medium and the integrity of the two ground decoding and display devices.

INTRODUCTION

The opportunity to conduct a preliminary investigation of the Air Traffic Control Radar Beacon System (ATCRBS) automatic altitude reporting correspondence with commercial aircraft arose when United Air Lines (UAL) purchased aircraft equipped with operating automatic altitude reporting systems were introduced into the east coast area. This was a welcome continuation of experimentation being conducted by the Federal Aviation Agency (FAA), Systems Research and Development Service (SRDS), National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N. J., and permitted extending the experimentation into a live environment to gain experience with automatic altitude reporting both from an airline standpoint and from an FAA controller's standpoint.

DESCRIPTION OF TESTS

All automatic altitude reporting correspondence data were taken with aircraft in normal flight configurations. Most of the data were taken with aircraft operating in the high altitude area of positive control environment. Some data were also taken during climb and descent. All flights were under the jurisdiction of the New York Air Route Traffic Control Center (NY ARTCC), and were conducted under instrument flight rules (IFR). NAFEC personnel were not involved directly or indirectly in the control of the aircraft. The collection of data was secondary to the normal flight procedures and each flight at all times remained in the ATC system.

Automatic readout of altitude reporting data was obtained each time the ground antenna scanned the target. Periodic verbal altitude reports were requested from the pilot during level flight and in a number of instances during climb and descent. These reports were initiated by the NAFEC operator by requesting the pilot to read out his altitude on a mark signal at the time the ground antenna scanned the target.

A total of 186 flights of Boeing 727 aircraft were monitored. Tabular correspondence data were taken only when the aircraft were established in level flights. Typical data collection flight profiles taken by two different ground decoding and readout systems are shown in Figs. 1 and 2.

A total of 17 flights of Douglas DC-8F aircraft were monitored. Each of these 17 flights provided data both during level flight and during climb or descent, using the previously described method. (One ground decoding system was used.) A typical data collection flight profile taken at the ground site is shown in Fig. 3.

One hundred seventy-six flights were monitored by a ground configuration using a special digital Beacon Video Processing Equipment and 42 flights were monitored by a conventional ground decoding configuration modified for 4096 codes and Altitude Transmission Equipment (ATE) decoding. Both systems used standard interrogators.

Twenty Boeing 727 flights were monitored by both decoding and display installations simultaneously, and a comparison of the data was made.

DESCRIPTION OF EQUIPMENT

Boeing 727 Airborne Configuration

Twenty-five UAL Boeing 727 aircraft (Shown in Fig. 4) were equipped with either Collins 621A-3 or RCA AVQ 60B ATC transponders with altitude reporting capability. Litton air data computers provided digitized barometric altitude data to the transponders for transmission to the ground. Digitized altitude was provided in increments of 100 feet, with switching at the 50-foot points; i.e., 50, 150, 250, etc.

In this installation transmitted altitude and the altitude indicated on the altimeter are not derived from a common computer source. The altitudes which were verbally relayed to NAFEC were from the standard (uncorrected) sensitive altimeters located on the instrument panel. The encoded altitude from the Litton air data computer (ADC) has only scale error correction. Altitude information used by the crew was provided by standard sensitive altimeter systems

The ATC transponder antenna was located on the underside centerline of the aircraft. Fig. 5 shows the transponder antenna configuration of the UAL Boeing 727 configuration.

Douglas DC-8F Airborne Configuration

The three UAL Douglas DC-8F aircraft (Fig. 6) which participated in the test were equipped with either Collins 621A-3 or RCA AVQ 60B

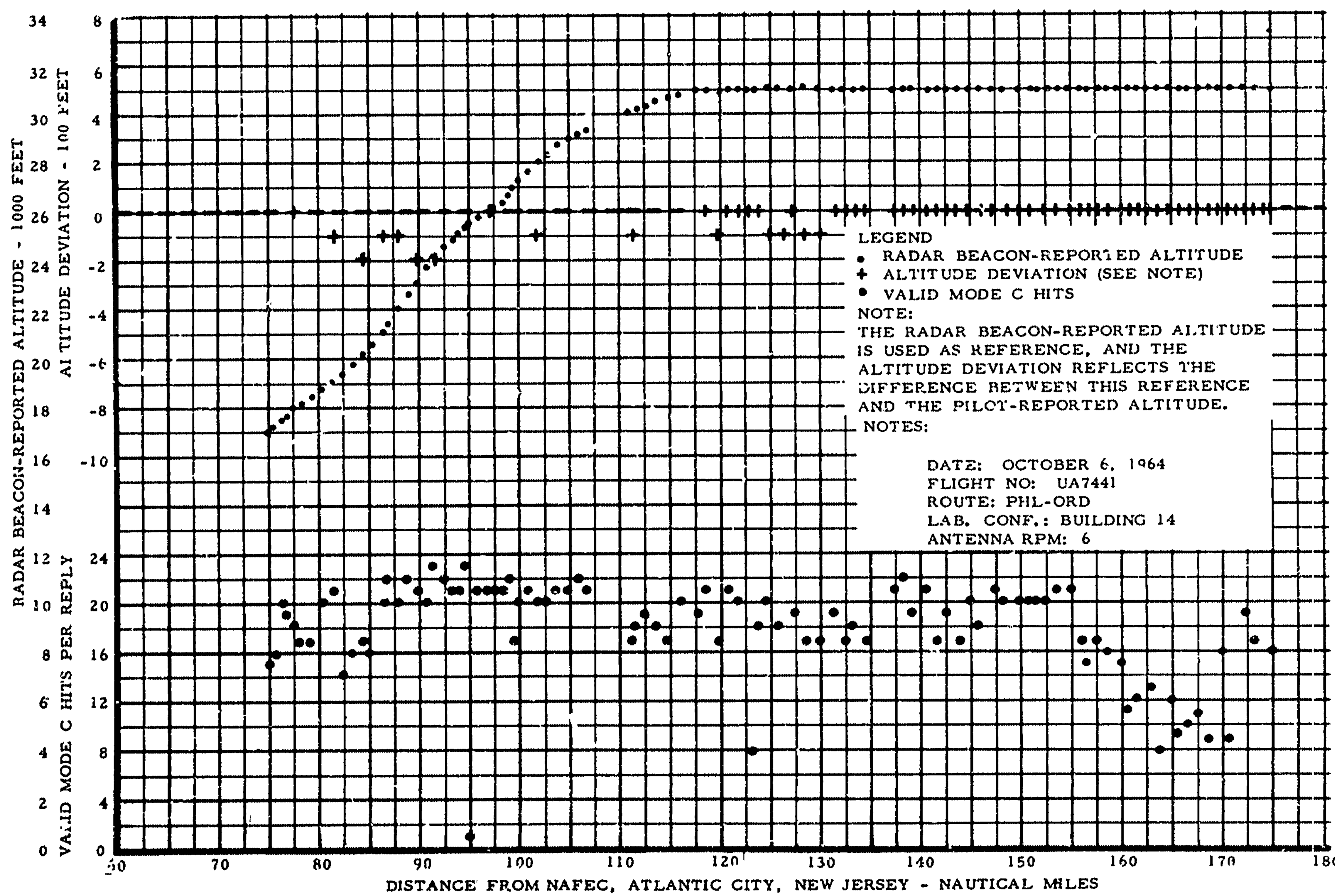


FIG. 1 B-727 FLIGHT PROFILE AS MONITORED AT NAFEC, BUILDING 14

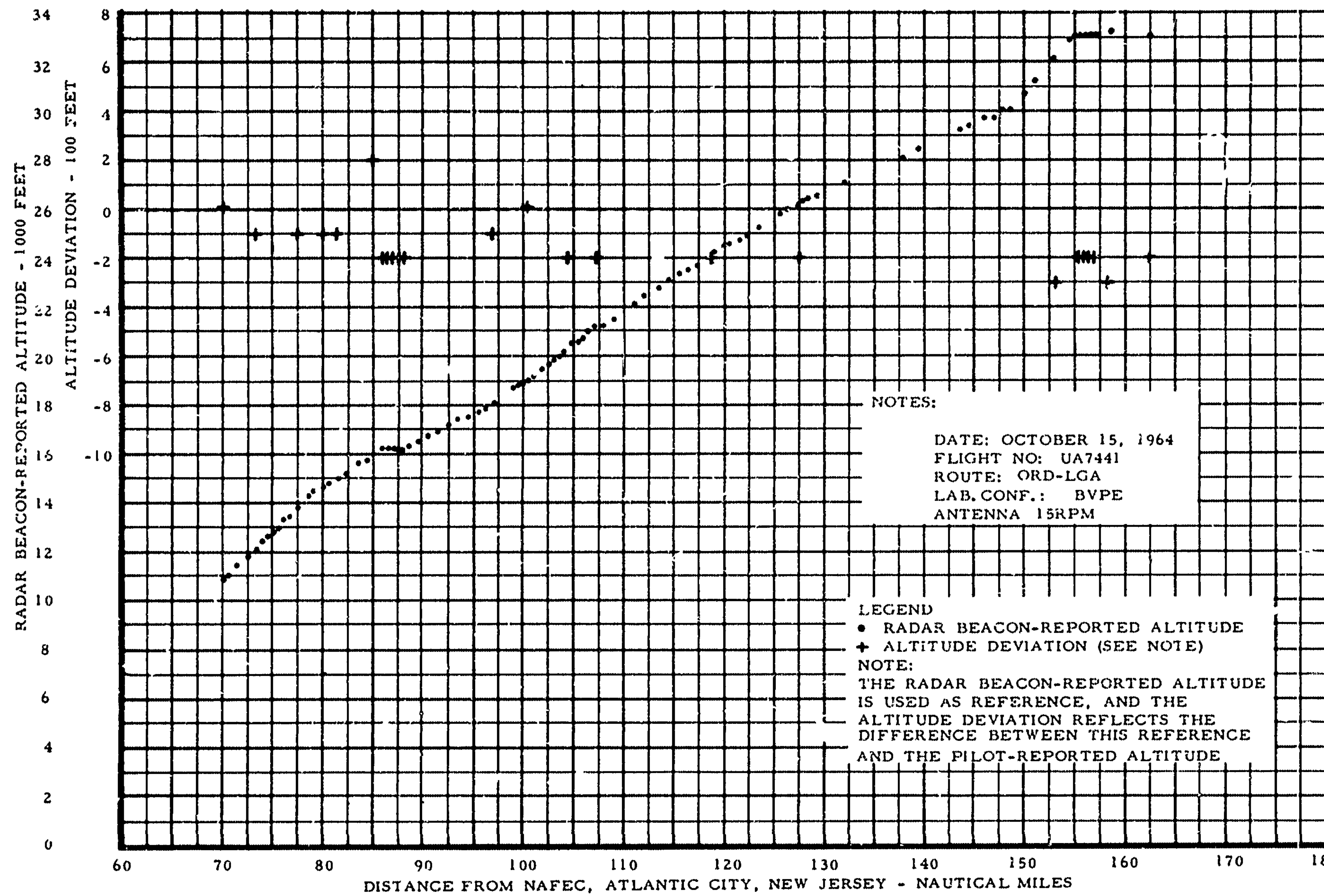


FIG. 2 B-727 FLIGHT PROFILE AS MONITORED AT NAFEC, BUILDING 149

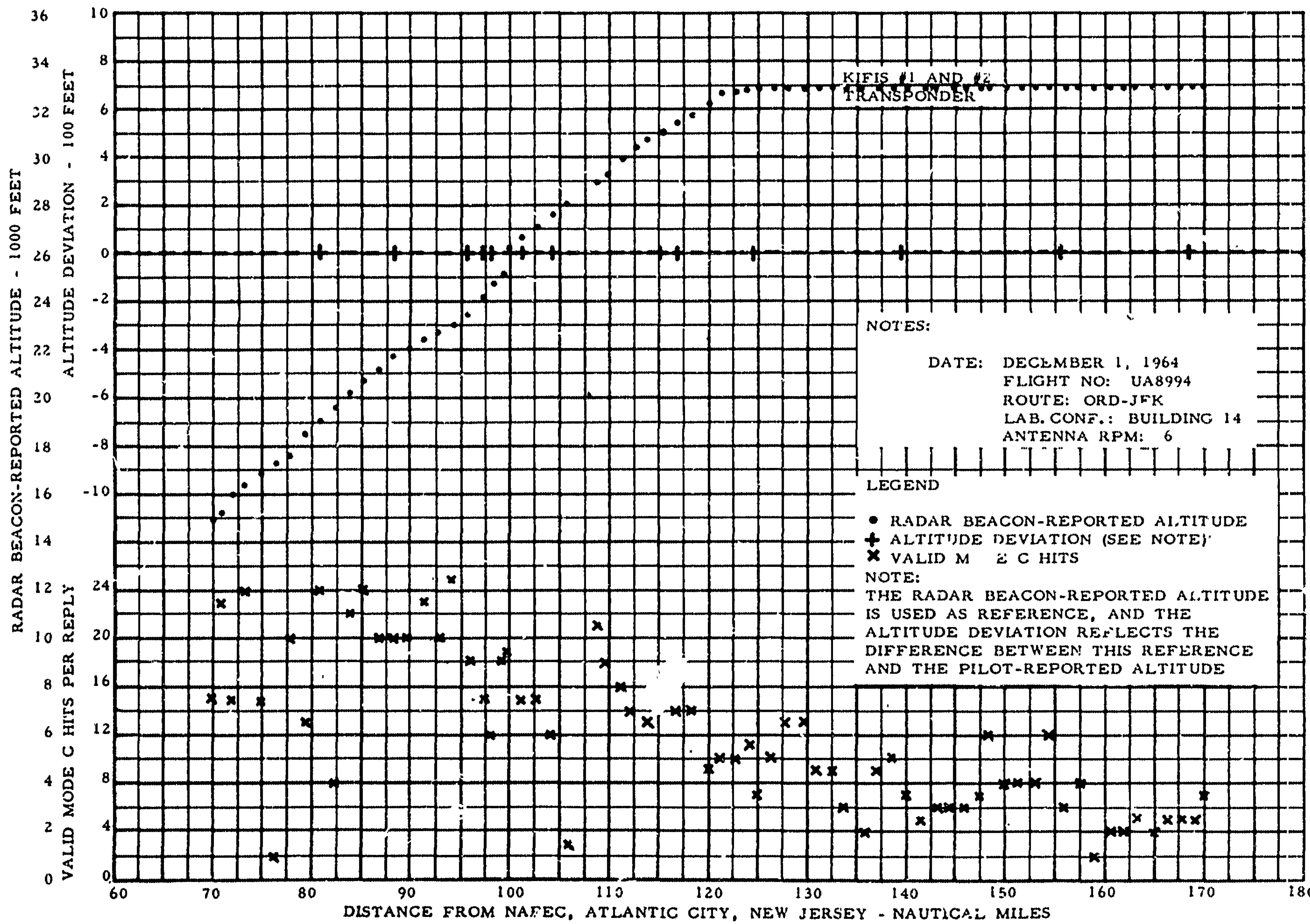
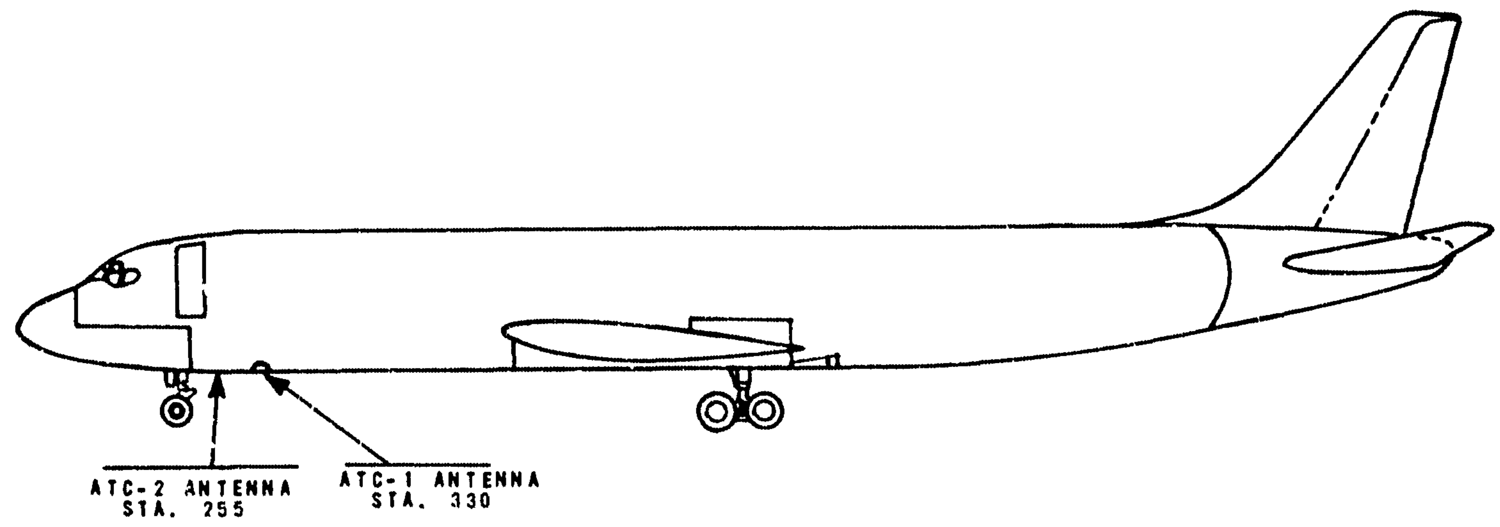
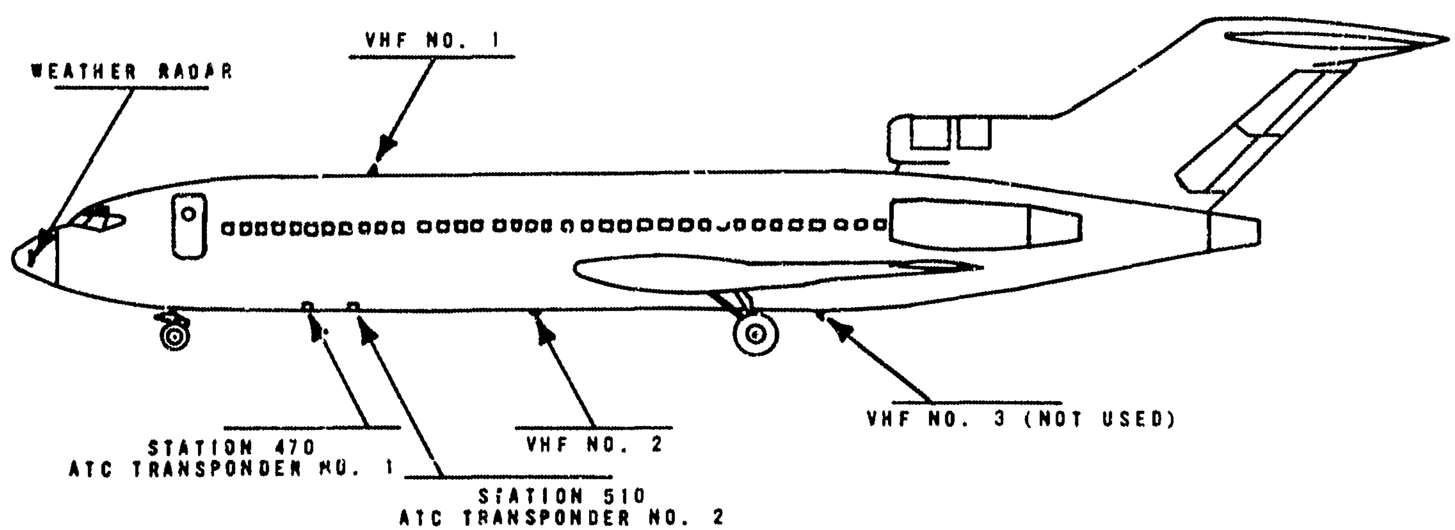


FIG. 3 DC-8F FLIGHT PROFILE AS MONITORED AT NAFEC, BUILDING 14

FIG. 4 UNITED AIR LINES BOEING 727 AIRCRAFT



A. UNITED AIR LINES DC-8F



B. UNITED AIR LINES B-727

FIG. 5 AIRCRAFT ANTENNA CONFIGURATION FOR ATC TRANSPONDER

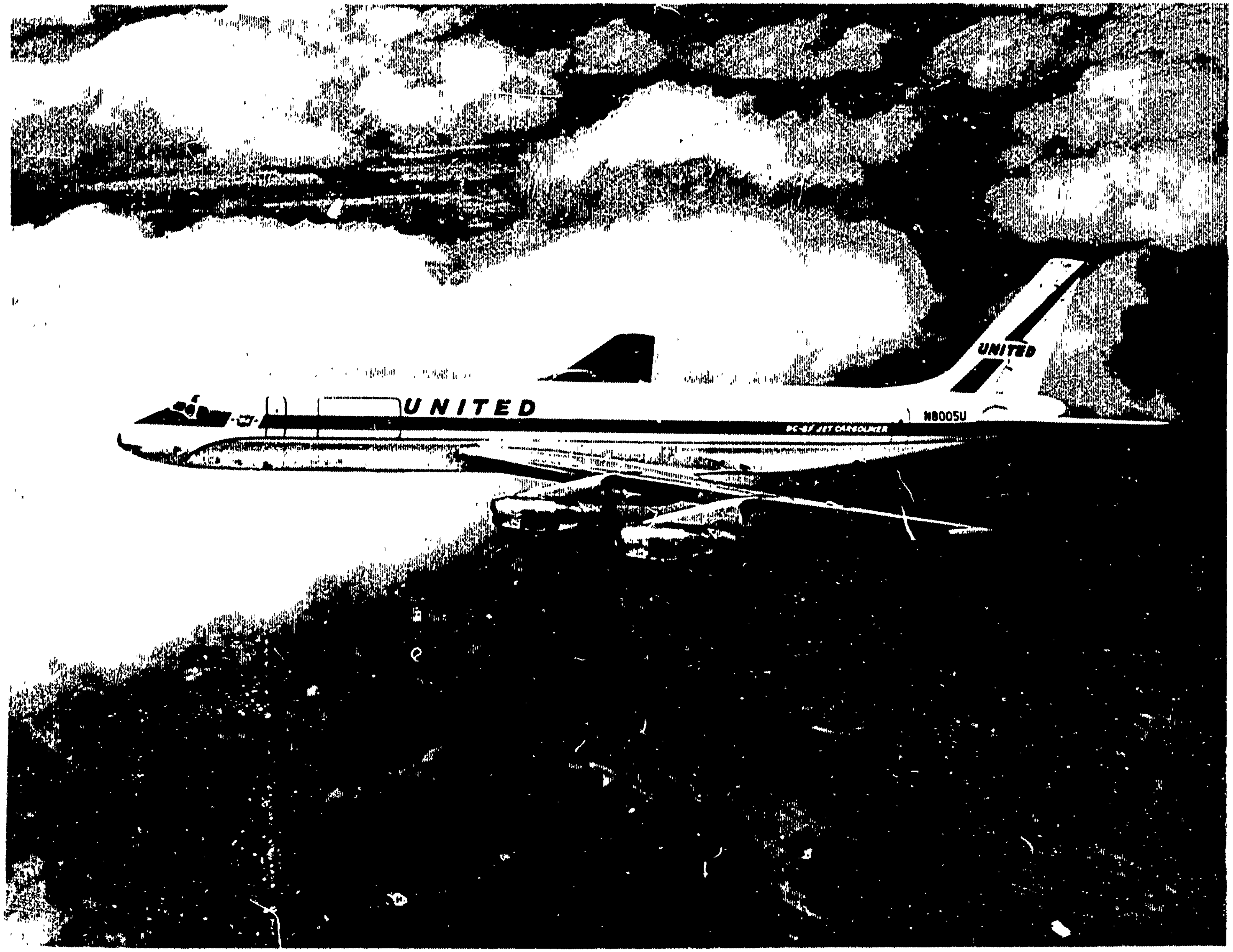


FIG. 6 UNITED AIR LINES DOUGLAS DC-8F AIRCRAFT

ATC transponders with altitude reporting capability. Kollsman Integrated Flight Instrumentation System (KIFIS) air data computers provided digitized barometric altitude data to the transponder for transmission to the ground. Altitude information used by the crew was provided by standard sensitive altimeter systems.

The altimeter and the altitude encoder in the DC-8F aircraft are a part of the KIFIS. Both have the same computer shaft position and, therefore, the encoder is furnished the same corrections provided to the altimeter. Two separate (one Captain's and one co-pilot's) altimeter/altitude encoders are provided by the KIFIS. The KIFIS air data computer has scale and mach error corrections.

The ATC transponder antenna was located on the underside centerline of the aircraft. Fig. 5 shows the antenna configuration for the UAL Douglas DC-8F.

NAFEC Ground Configuration

A description of the NAFEC Ground Configuration is included in Appendix I.

TEST RESULTS

Boeing 727 Aircraft Correspondence

A summary of all the flight test data is presented in Appendix II. Table I shows the number of times each aircraft was monitored and the altitude correspondence obtained during a given flight. A histogram which shows all the altitude correspondence data is shown in Fig. 7. It is to be noted that the correspondence difference remained essentially constant throughout all samplings of a given flight. While large numbers of data points were taken on each flight, values of correspondence difference remained essentially constant and thus only a single number is shown for each flight.

Observations of correspondence were made during climb and descent although the test was not designed to yield optimum data during these flight phases. Indications are that correspondence differences during climb and descent were essentially the same as those observed during level flight. While these observations are of limited value they are corroborated by previous work done using NAFEC aircraft.

Douglas DC-8F Aircraft Correspondence

A summary of all the flight test data is presented in Table II and shows the number of times each aircraft was monitored and the altitude

TABLE I

ALTITUDE CORRESPONDENCE AS A FUNCTION OF AIRFRAME

B-727

A		B		C		D		E		F		G		H		I		J	
Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.
9/15	0	9/4	-2	9/9	-2	9/16	0	9/2	0	9/8	0	9/22	0	9/2	-2	9/1	0	9/4	0
		9/4	-2	9/17	-2			9/4	0	9/10	+1	10/5	0	9/9	-2	9/3	0	9/10	+1
		9/15	-2	9/21	-1			9/10	0	9/10	0	10/7	-1	9/11	-3	10/2	0	9/14	+2
		9/15	-2	9/21	-2			9/14	+1	9/16	0			9/14	-2	10/2	+1	9/16	+3
		9/17	-3	9/28	-4			9/21	+1	9/16	-1			9/14	-3	10/16	-1	9/22	+1
		9/17	-2	9/30	-3			9/21	+1	9/23	-1			9/25	-1			9/25	+2
		9/23	-1	9/30	-3			9/25	0	9/23	-1			10/5	-1			9/30	+1
		9/23	-2	10/7	-3			9/25	+2	9/28	-1			10/5	-1			10/8	+2
				10/7	-4			9/28	+2	10/1	-1							10/8	+3
				10/16	-4			9/29	+1	10/6	-1							10/13	+2
								10/2	+1	10/13	-1							10/13	+3
								10/2	+1	10/14	-1							10/14	+1
								10/7	+1	10/16	-1							10/14	0
								10/13	0										
								10/13	0										
								10/16	0										

K		L		M		N		O		P		Q		R		S		T	
Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.	Date	Dev.
9/17	+5	9/3	0	9/9	+4	9/2	+3	9/2	-1	9/24	+6	9/1	0	9/17	-2	9/3	-1	9/11	+1
9/22	-6	9/3	0	9/11	-3	9/11	+3	9/9	+5	9/24	+5	9/1	0	9/21	-3	9/11	-2	9/14	-5
9/24	-6	9/3	+1	9/18	+3	9/11	+5	9/9	+5	9/28	+4	9/18	+1	9/28	-3	9/11	-3	9/16	+2
9/24	-6	9/4	0	9/22	+2	9/18	+5	9/16	+1	10/5	+4	9/25	+2	9/30	-2	9/18	-2	9/18	+1
9/29	-6	9/9	-1	9/24	+3	10/6	0	9/16	+1	10/5	+5	9/25	+2	10/2	-4				
9/30	-6	9/14	+1	9/24	+4	10/6	0	9/16	0	10/8	+5	9/29	+1	10/6	-3				
9/30	0	9/24	0	10/5	-1	10/13	0	9/21	0	10/16	+6	9/29	+1	10/8	+1				
10/13	0	10/2	+1	10/5	+3	10/14	0	9/23	[illegible]	10/14	-3	9/29	+1						
10/15	0	10/15	-1	10/7	+2			9/23	-1			10/1	+1						
10/15	0	10/15	-1	10/7	+1			9/25	-1			10/1	+2						
		10/15	0	10/16	+3			9/30	-1			10/1	-1						
								9/30	0			10/5	0						
								10/2	0			10/7	+2						
								10/5	-2			10/14	0						
								10/6	+1			10/14	+1						
								10/6	0			10/14	0						
								10/13	+2										

U		V		W		X		Y	
Date	Dev	Date	Dev	Date	Dev.	Date	Dev	Date	Dev.
9/22	-1	9/30	-2	10/14	+1	9/28	0	10/2	+2
9/22	-1	10/2	-2	10/14	+1	10/1	+1	10/7	-2
10/6	-2					10/2	-1		

NOTE: Bold letter heading of each major column is the code identifier of airframe number.

Dev - Altitude deviation in multiples of 100 feet

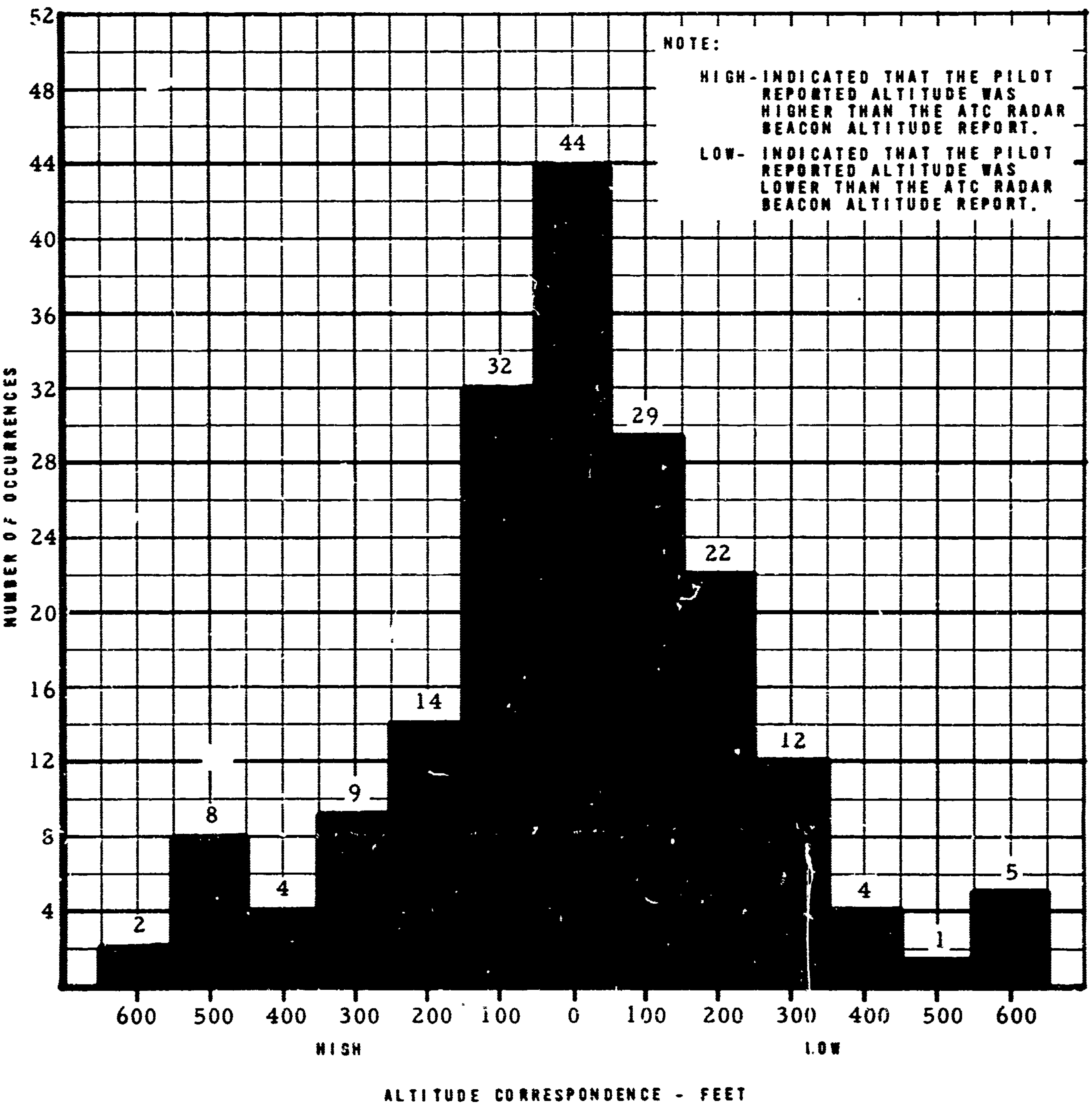


FIG. 7 HISTOGRAM OF ALTITUDE CORRESPONDENCE

TABLE II

SUMMARY OF UAL/FAA RADAR BEACON ALTITUDE REPORTING FLIGHTS MONITORED

DC-8F

DATE	FLIGHT NO.	KIFIS	TRANSPONDER	AVERAGE DEV.	PILOT DEV. LOW	READOUT DEV. HIGH	NO. OF SAMPLES	ASSIGNED ALTITUDE
				FRAME AA				
11/18/64	UA8995	1	1	+12	-50	0	12	28,000
11/25/64	UA8994	2	2	+30	-20	+ 70	4	33,000
11/26/64	UA8995	1	1	+19	0	+ 45	11	31,000
12/3/64	UA8994	1	1	0	0	0	4	33,000
				FRAME BB				
11/20/64	UA8995	1	1	-10	-50	+ 10	6	31,000
		2	2	-60	-60	- 60	2	31,000
11/28/64	UA8994	2	2	0	0	0	1	37,000
11/28/64	UA8995	1	1	0	0	0	1	31,000
12/12/64	UA8994	1	2	+60	+60	+ 80	4	37,000
		2	1	+80	0	+ 80	1	37,000
12/12/64	UA8995	1	1	+31	-20	+ 25	5	28,000
		1	2	+70	+50	+ 80	3	28,000
		2	2	-40	-60	- 30	5	28,000
		2	1	-66	-70	- 60	3	28,000
				FRAME CC				
11/18/64	UA8994	1	1	0	0	0	3	33,000
11/19/64	UA8995	1	1	+ 84	+60	+100	5	28,000
		2	2	+ 45	0	+ 90	4	28,000
11/24/64	UA8994	2	2	+ 22	0	+ 40	4	33,000
		1	1	+ 18	+60	- 20	3	33,000
11/24/64	UA8995	2	2	+ 20	+ 5	+ 40	10	31,000
12/1/64	UA8994	1	2	+ 50	+50	+ 75	4	33,000
12/2/64	UA8995		2	+105	+80	+120	5	28,000
		2	1	+ 20	+20	+ 20	2	28,000
		1	1	+100	0	+160	5	28,000
		2	2	+ 14	+10	+ 20	5	28,000
12/2/64	UA8994	2	1	0	0	0	2	32,000
12/3/64	UA8995	2	2	+ 34	-30	+ 90	21	28,000

Overall Average	+23
Total Samples	137
Max. Low Reading	-66
Max. High Reading	+160

correspondence obtained during a given flight. The correspondence difference during these tests was essentially zero for most flights. For this reason, and because the time of day during which the tests were run permitted more communication with the crews, an attempt was made to gather more refined data. In this way it was possible to obtain data in smaller increments than the 100 feet which is the basic grain size of the reporting system. Observations of correspondence were made during climb and descent although the test was not designed to yield optimum data. However, on several flights a special technique was used to obtain good time correlation of the data comparison -- air and ground.

On several flights barometric correction was inserted into the ground decoding system when the aircraft reported leaving standard (29.92) settings. In these cases a ground correction was inserted to correspond to the pilot's report of barometric setting. The correspondence differences of no more than 100 feet were recorded under these conditions.

The Douglas DC-8F aircraft were equipped with dual KIFIS air data computers and dual transponders. On several of the flights the crews switched transponders and air data computers to various combinations so that differences in correspondence could be examined. On one occasion, during a portion of one flight, a difference of 160 feet was reported. On all other observations, essentially zero correspondence difference was found.

Effects of Turbulence

The data collected appeared to show that pilots attempted to maintain level flight during data collection. On two occasions the ground observers noted altitude fluctuations; crews were queried and confirmed the presence of turbulence. During these periods the altitude readout on the ground display fluctuated between 200 feet low and 200 feet high from the previous verbally reported altitude.

Adequacy of the Transmission Medium

The maximum surveillance radius of the ATCRBS is 200 nm. Fig. 8 shows the geographical area and airways structure which were monitored for these tests. Table III shows the flight levels used by the monitored aircraft.

On outbound flights departing from Newark, N. J.; La Guardia, N. Y.; and Philadelphia, Pa., the aircraft were generally detected at 5000 feet altitude and climbing. The climbout normally continued to altitudes ranging from 18,000 to 39,000 feet. The target remained on the radar scope out to a range of approximately 180 nm. Depending on the traffic situation and rate of climb, some aircraft were out of the surveillance area prior to reaching cruise flight phase.

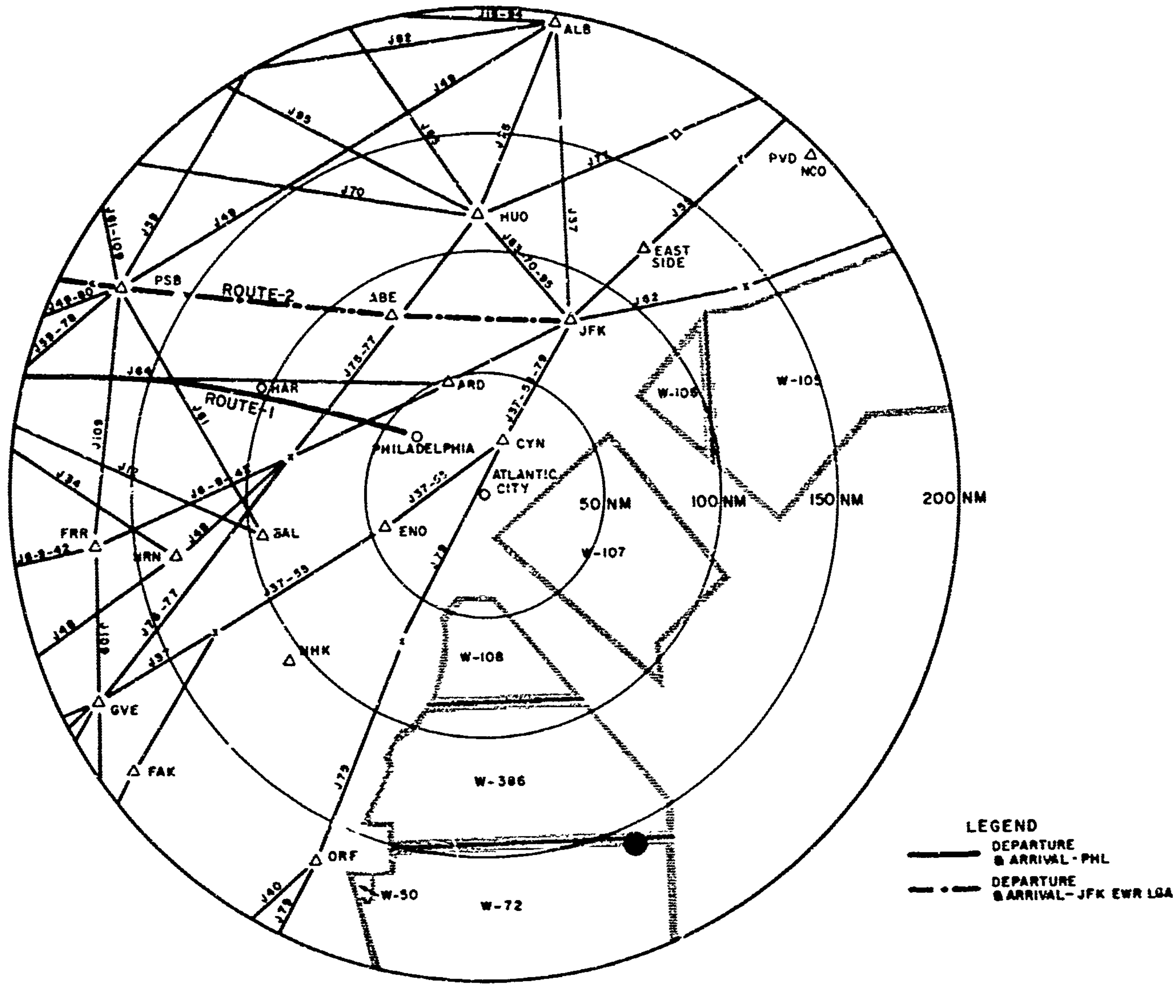


FIG. 8 NAFEC ATC RADAR BEACON SURVEILLANCE AREA

TABLE III

ALTITUDE DISTRIBUTION CHART

B727 FLIGHT LEVEL	NO. OF OCCURRENCES
18,000	1
19,000	2
20,000	2
21,000	1
22,000	1
23,000	1
24,000	7
25,000	5
26,000	4
27,000	4
28,000	8
29,000	4
30,000	2
31,000	28
32,000	0
33,000	25
34,000	2
35,000	82
36,000	0
37,000	3
38,000	1
39,000	3
	TOTAL 186

DC-8F FLIGHT LEVEL	NO. OF OCCURRENCES
28,000	5
31,000	4
32,000	1
33,000	5
37,000	2
	TOTAL 17

Inbound flights to Newark and La Guardia were normally detected near Philipsburg, Pa. Flights to Philadelphia were normally detected near Harrisburg, Pa. In certain instances there was a lack of cruise information since the aircraft had started their descents.

On a scan by scan comparison of ATC radar beacon returns it was observed that the coverage and signal adequacy of altitude reporting (Mode C) and identity replies (Mode A) were essentially the same. It was further observed that returns were received consistently on a scan by scan basis. This was to be expected since most of the flights were observed while in level flight. In isolated instances, aircraft data were obtained during maneuvers and some loss of signal resulted from aircraft shadowing because of changes in attitude. This is an inherent characteristic of this system and has frequently been experienced in operation.

An examination of transponder altitude reporting replies per scan on a selected series of flights showed that satisfactory altitude display was achieved for valid Mode C reply rates (hit-count) as seen by the special purpose decoder (ATE), ranging from as low as two hits per scan to 20 or more hits per scan.

Decoder and Display Comparison

Twenty flights were monitored by both decoder and display installations. Different decoding-displayed techniques are used in the two installations. A comparison of the data displayed on the two separate systems on the 20 flights showed the information to be identical. Therefore, it was established that the ground equipment did not contribute to any difference in correspondence.

CONTROLLER COMMENTS

Review Notes: As stated on Page 1, the purpose of this test series was to obtain information on correspondence between altitude information displayed to the pilot and the altitude data transmitted to the ground. Information was also gathered on the adequacy of the transmission medium, ground ATCRBS equipment, and normal altitude fluctuations as observed on the ground. Besides these prime test objectives that are supported by factual data, this report points out other areas that must be considered before the Mode C pressure altitude reporting capability can be implemented. The controller comments in this report deal with the application of automatic altitude reporting in air traffic control operations. They are based on a limited amount of data and are not in prime support of the test objectives. The reason for including them

as a by-product is to point out the need for additional effort on the part of the Agency to integrate these features procedurally into the National Airspace System.

The concensus among the nine controllers participating in the test was that the altitude reports received from the ATC radar beacon systems were beneficial in clarifying air situations such as rate of climb, degree of turbulence, etc., for planning airspace movement, etc.

In the opinion of several participating controllers, application of automatically reported altitude will reduce the amount of radar vectoring required to ensure adequate vertical spacing during handoff between sectors or facilities. It was also felt that automatic altitude reporting would reduce vectoring of descending aircraft since altitude information would be available on the aircraft flying at other levels. In the event immediate descent is desired by the pilot due to turbulence, icing, etc., the automatic altitude reporting capability in aircraft which might interfere with descent would expedite the controller's decision to permit an immediate descent. The availability of the radar beacon automatic altitude would add meaning to traffic information given to pilots and would in many cases eliminate the need for traffic advisories.

However, the test results obtained suggested some concern to a controller who up to now had the pilot's verbally reported altitude as reference. Now the information is automatically displayed and may be different from the expected altitude. Consequently, doubts arose in the minds of the nine controllers as to the confidence to be placed in the new information if correspondence differences of the magnitude observed in these tests (up to 600 feet) must be taken into account. The feeling of the controllers was that significant differences between the altitude seen by the controllers and the altitude seen and used by flight crews would seriously detract from the value of automatically reported altitude.

It was feared that automatic altitude reports might not be used for altitude vacating functions, or vertical movement of aircraft for collision prevention, or sequencing of aircraft movement if significant correspondence differences are permitted. Accordingly, the application of vertical separation standards would still be predicated on voice confirmed reports.

Review Notes: These controller comments might appear to the reader to give no recognition to the fact that a significant discrepancy between the assigned and the automatically reported altitude ought to immediately arouse suspicion. A controller would hardly accept such a discrepancy without questioning the pilot in an attempt to establish the cause.

It must be recognized that no standards now exist establishing a required tolerance for correspondence between the pilot's altitude indicator and the digitized output to the radar beacon transponder. Had such standards been in effect and the equipment in the participating aircraft been operating in conformance with those standards, the concern expressed above would have been allayed. It is evident, then, that early establishment of such standards is a paramount need.

While the magnitude of correspondence difference had one effect on the controllers at NAFEC who did not have the responsibility of controlling the aircraft, a different reaction might have been experienced by the controller with this responsibility.

This series of tests brings to the foreground a number of questions deserving attention prior to the time that full benefit of the system can be achieved.

1. What is the maximum correspondence difference with which the controller will have to cope?

2. Should separate altitude sources be used without pilot display of the information being fed to the altitude transmission system?

3. What effect would correspondence differences have on situations where flight plan altitude is not displayed on an alpha-numeric display and only beacon reported altitude appears? Would the controller act based on this information or would he confirm it by voice?

4. What effect would correspondence differences have on a controller working many aircraft in an alpha-numeric display environment in which both flight plan altitude and beacon reported altitude are displayed?

5. If a variety of altitude reporting configurations with significantly different correspondence values are introduced into the system by various users, might it be necessary for controllers to be aware of these differences in order to cope with the traffic efficiently?

ANALYSIS OF RESULTS

The overall correspondence difference resembles a Gaussian distribution (See Fig. 7) with a standard deviation (67% of observations) within 232 feet of the altitude report. The spread of difference was from +600 to -600 feet and the arithmetic mean difference was -2.7 feet, an essentially negligible amount.

In the Boeing 727 aircraft 500 to 600-foot correspondence differences were consistently noted on certain of the aircraft during early parts of the test. These differences were due to several reasons. First, in Boeing 727 aircraft the transmitted altitude and the altimeter altitude are not derived from a computer source that is common to both. For this reason, there will be some difference between the transmitted altitude and the altimeter reading which the crew relays to the ground. There will also be another difference due to the fact that the Litton air data computer and the altimeter are connected to two different pitot-static sources. A third reason is the fact that the Litton air data computer corrects the encoded altitude for scale errors and the cockpit altimeters were original items with the delivery of the Boeing 727 aircraft. Altitude modules were not required to be used and were not in use operationally. The encoded altitude output had changed and no effort had been made to call these units in for calibration since there had been no need for this particular function. When the large differences in reported altitudes were observed, equipment was replaced with overhauled units having zero time. No line adjustments to equipment or the airplane system were made. After United Air Lines changed four specific units which were showing large correspondence differences, these differences were reduced to very small values; consequently, good correspondence was achieved. (See Appendix III.)

It is recognized that the ATC system has always accommodated the difference between the flight plan altitude and the actual altitude seen at any moment by the pilot, but it must be remembered that the altitude seen by the pilot was not displayed to the controllers. Thus, if in a future program flight plan altitude and beacon reported altitude are both shown to the controllers, they may be faced with a dilemma resulting from differences between the two numbers viewed. The increment size of the automatic altitude reported data can be a factor in this difference. Further effort is required to determine the effects of these differences on the air traffic controller.

> Review Notes: The accommodation of altitude differences is not radically different from the situation which existed at the time that surveillance radar was introduced into air traffic control. Prior to that time, deviations from course were accommodated only by tolerances applied to the navigation system used by the pilot, just as similar tolerances appear in vertical separation minima for the same

purpose. With surveillance radar, when a pilot's deviation from course as observed on radar is likely to jeopardize lateral separation between his aircraft and another under radar observation, the navigation system tolerances can no longer be depended on to guarantee lateral separation. A similar situation will begin to exist with operational implementation of automatic pressure altitude reporting, although the controller response will necessarily have to be different.

When automatically reported altitude data reveal a situation in which two aircraft on converging courses may be separated by less than the required vertical spacing, the controller normally would not direct one of the aircraft to change altitude. Pilots would much prefer to execute a turn instead of an altitude change. Therefore, indicated lack of vertical separation would best be corrected by a radar vector.

The question naturally arising here is: What if, for example, due to correspondence and other errors, the higher aircraft is indicated as being 100 feet below its assigned level, while the lower one is indicated as being 200 feet above its assigned level. The answer to this is that control procedures will have to be developed to recognize the existence of certain tolerable errors in the data presented. With this in mind, the programing documentation for the NAS Stage A, Model I computer program specifies that the computer will inhibit display of Mode C altitude/flight level data as long as it shows that the aircraft is indicated to be within a certain parameter (Two hundred feet is used as a starting point) of the assigned level.

When Mode C data are displayed to the controller by other systems not having this inhibit capability, the control procedures for using the displayed data would specify a similar parameter. Consequently, assuming a parameter of 200 feet in the example cited, the two aircraft would be considered to be adequately separated vertically until one was indicated to have deviated 300 feet or more from its assigned level in the direction of the other aircraft. Of course, no action would be required if the indicated deviation were in the direction away from the other aircraft, unless a third aircraft were involved.

An alternative would be possible if sufficient time were available. When a significant deviation was noted between the automatically reported data

and the assigned level, the pilot would be queried to determine if an erroneous altimeter setting was being used or he had actually deviated from his assigned level. However, if time for such a discussion were not available, the controller would have to act on the basis that the automatically reported data were actually indicating a dangerous situation and ask questions afterward.

Other procedures will have to be spelled out to cover such circumstances as would be indicated by a true situation when (due to malfunction) the altitude data displayed to the pilot differed significantly from that automatically reported to the controller.

Undoubtedly, this would have been determined as in the previous example by the inquiry addressed to the pilot to determine whether an error existed. If it did, the control procedure would direct that the controller disregard the automatically reported data, or take the indicated error into account in future control. Alternatively, the pilot might be directed to turn off Mode C.

CONCLUSIONS

It is concluded that:

1. The ground equipment did not contribute errors of its own to the automatically reported altitude.

2. The ATC Radar Beacon transmission medium performed satisfactorily, and adequate area coverage (for both Modes A and C) was obtained throughout the test program over the surveillance area observed.

3. Greater correspondence differences occurred when the beacon transmitted altitude and the altimeter indication in the cockpit were derived from two different sources; i.e., United's B-727 vs DC-8F's.

4. The Air Traffic Controllers who participated in these tests were concerned over potential utility of automatic altitude reporting if significant correspondence differences are permitted in the system.

RECOMMENDATIONS

It is recommended that:

1. A study be made of the various airborne configurations likely to be used with a view toward defining a limit on correspondence difference which is acceptable operationally, and feasible economically. The Agency should take early steps to establish and publish the maximum correspondence limits which can be tolerated in ATC operations.

2. The application and role of automatic altitude reporting in the air traffic control environment be further defined in terms of standards and procedures; e.g., control procedures should:

a. Reflect the action controllers should take when small differences appear between a flight's assigned level and its automatically reported altitude or flight level; and,

b. Provide for verifying automatically reported altitude or flight level by communication with the pilot whenever a large difference is noted and, subsequently, direct what measures should be taken if corrective action does not resolve the problem, etc.

3. Operational investigation be continued both by simulation and live experimentation to determine the most effective use of automatic altitude reporting in the air traffic control environment.

ACKNOWLEDGEMENTS

The authors wish to thank Dean L. Gensamer and John Deckman, Air Traffic Control Specialists; all project members from the NAFEC Air Traffic Control Pool; and the Eastern Region, whose team efforts contributed to the successful completion of the investigation.

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Appreciation is also extended to the Detection Systems Branch, RD-240; Beacon Systems Section, RD-242; and the System Design Team, RD-14 and RD-17, for their valuable advice and guidance.

Acknowledgement is made to United Air Lines and the Air Transport Association of America, whose tremendous cooperation and sincere interest made the test program a reality.

APPENDIX I

NAFEC GROUND CONFIGURATION

NAFEC has two independent ATC radar beacon installations with the capability to decode radar beacon altitude reports and display the associated information.

1. Beacon Video Processing Equipment (BVPE)[1] is a special purpose ATC radar beacon decoder with capabilities to decode 4096 beacon identity and beacon altitude reports in 100-foot increments. The beacon information is numerically displayed on NIXIE lights in octal form for the identity indicator panel and in decimal form for the altitude indicator panel. This equipment was the prime decoder during the UAL/FAA tests and was used in conjunction with the Eastern Region's Air Traffic Control Beacon Interrogator (ATCBI-3) installed at the Airport Surveillance Radar (ASR-4) site. The radar beacon receiver was ungated to provide video out to a range of 180 nautical miles or more. The interrogator was operated in Mode A and Mode C. The ATCBI-3 antenna was installed on an ASR-4 antenna which rotated at 15 revolutions per minute (rpm).

The BVPE Control and Indicator Panels were mounted beside a Radar Indicator AN/UPA-35, or a Plan Position Indicator (PPI), as shown in Fig. I-1, and were part of the NAFEC Experimental Air Traffic Control Facility located in Building 149. This configuration provided two methods of obtaining rapid readout and a digital display of desired beacon information.

a. A pencil light gun to obtain NIXIE light readouts (numeric) on a target displayed on PPI. The readout occurs each time the cathode electron beam is intensified as it passes through the target at which the light gun is aimed. Generally used to obtain information on aircraft using nondiscrete codes or unknowns.

b. A select code button to obtain NIXIE light readouts (numeric) on an aircraft assigned to a discrete code (identity).

This report refers to the aforementioned installation as the NAFEC Building 149 configuration.

[1]Final Engineering Report, Contract FAA/BRD-224, Burroughs Corporation, "Beacon Video Processing Equipment," dated July 31, 1962

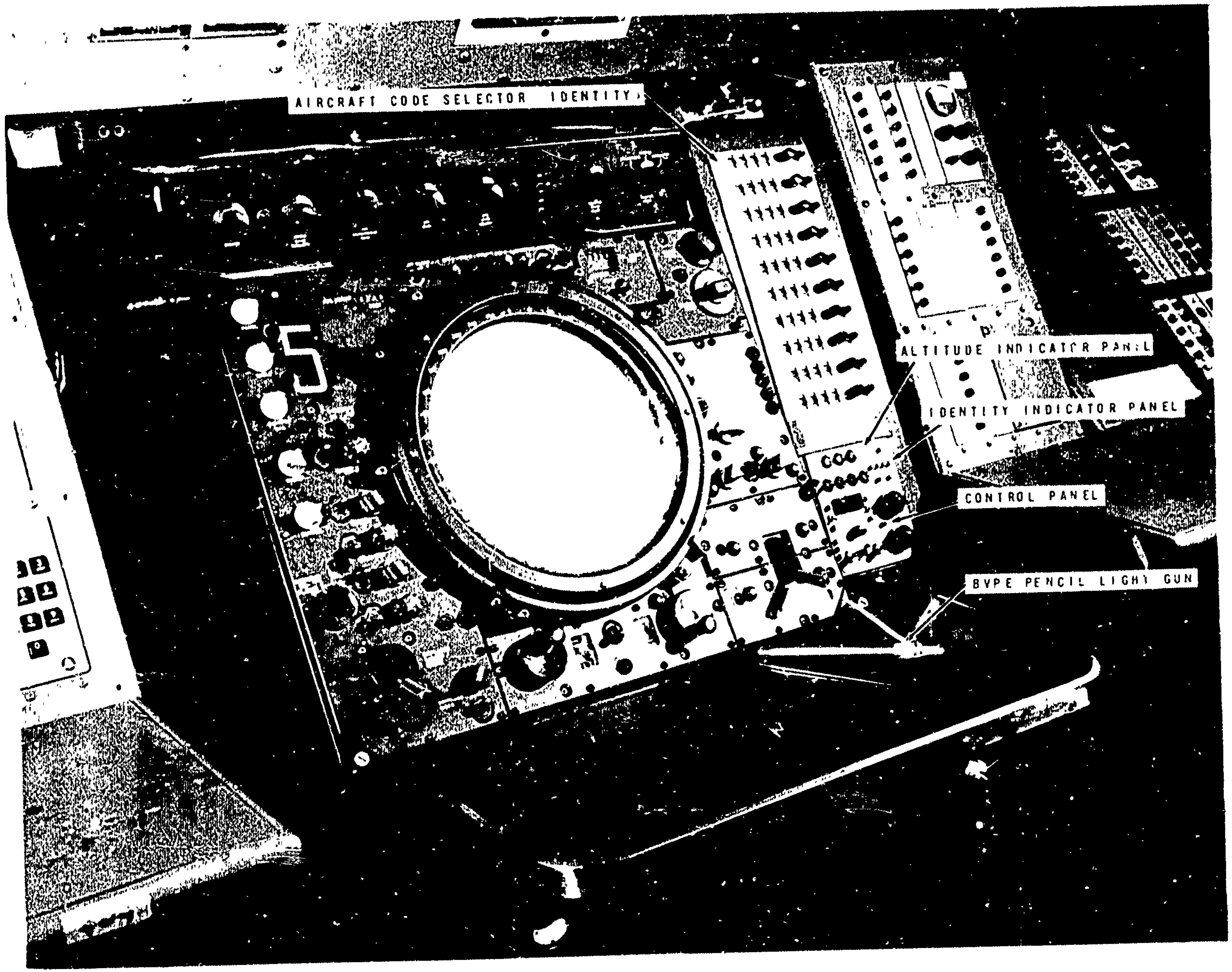

FIG. I-1 RADAR INDICATOR AN/UPA-35 AND BVPE CONTROL AND INDICATOR PANELS

2. The ATC Radar Beacon Laboratory[2] provides a single-target tracking with altitude and identity readout on a scan conversion display and utilizes primarily equipment similar to that being used in the present air traffic control environment, except for the ATE decoder. This includes the transmitter site, decoder site, and indicator site equipment of the ATCBI-2 system and a Radar Bright Display Equipment (RBDE-5). Fig. I-2 shows the ATC radar controller's position. In the course of ~~-imentation, the installation has been modified to include:

a. 4096 beacon identity (Mode A) decoding

b. Mode C with altitude decoding

c. Numeric presentation of beacon identity and altitude information on an RBDE-5, which utilizes a scan conversion technique to provide a television-type display of the PPI.

d. Automatic positioning of a set of numeric characters (altitude and identity information) adjacent to one target per scan of the antenna, as shown in Fig. I-3.

(1) A slewing stick which places a gating symbol over an unknown beacon target; identifies the PPI target by placing the beacon altitude and identity information adjacent to the target.

(2) A modified beacon control box to select discrete identity and to locate the target on the PPI display automatically and place the beacon altitude and identity information adjacent to the target. As long as the target identity is selected, the altitude and identity information will track with the target and will be updated with each scan of the antenna.

The ATCBI-2 antenna was installed on an ASR-3 antenna which normally rotates at 15 rpm; however, a variable speed drive motor was installed. Subsequently, the antenna was rotated at 6 rpm for this investigation. The antenna installation is shown in Fig. I-4.

The Altitude Transmission Test Set (ATE) built by Airborne Instruments Laboratory for FAA under Contract FAA/BRD-365 was used for altitude decoding.

This report refers to the aforementioned installation as the NAFEC Building 14 configuration.

[2] Report No. RD-64-73, Memorandum Report, Project 108-X, "Air Traffic Control Radar Beacon System Experimental Facility at NAFEC," dated May 1964

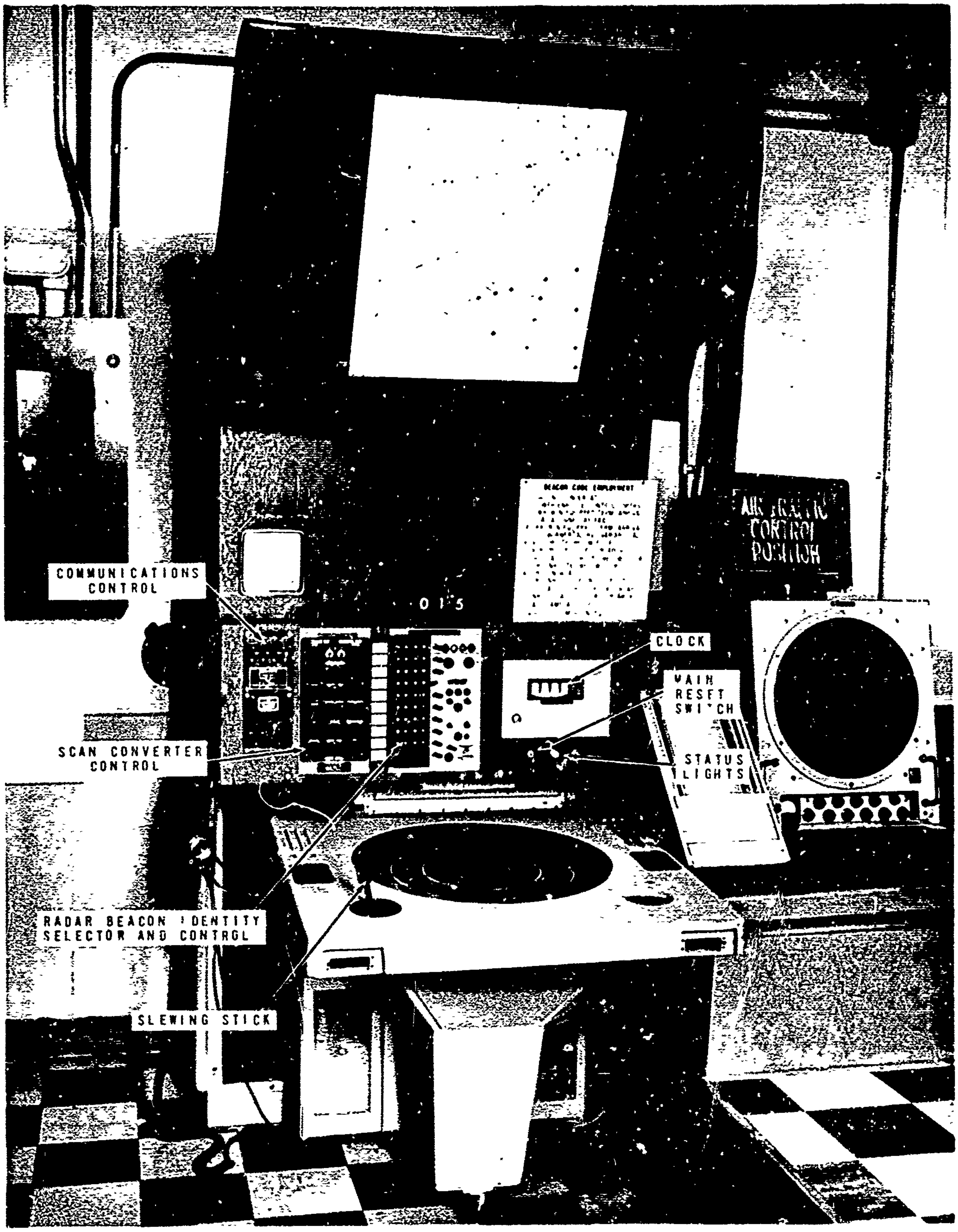

FIG. 1-2 ATC RADAR CONTROLLER'S POSITION (NAFEC, BUILDING 14)

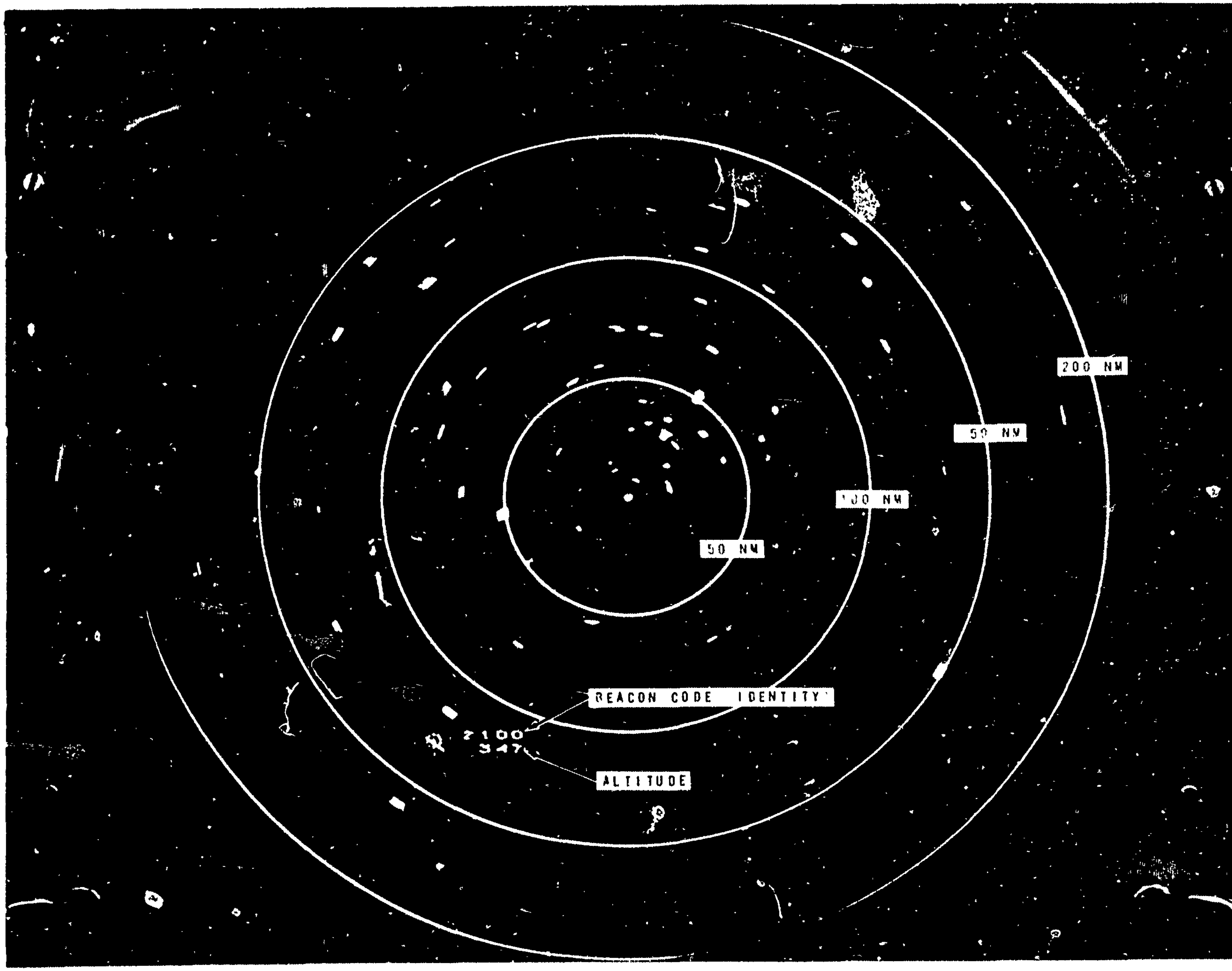

FIG. I-3 NUMERIC READOUT OF A BEACON REPLY AT THE TV DISPLAY POSITION

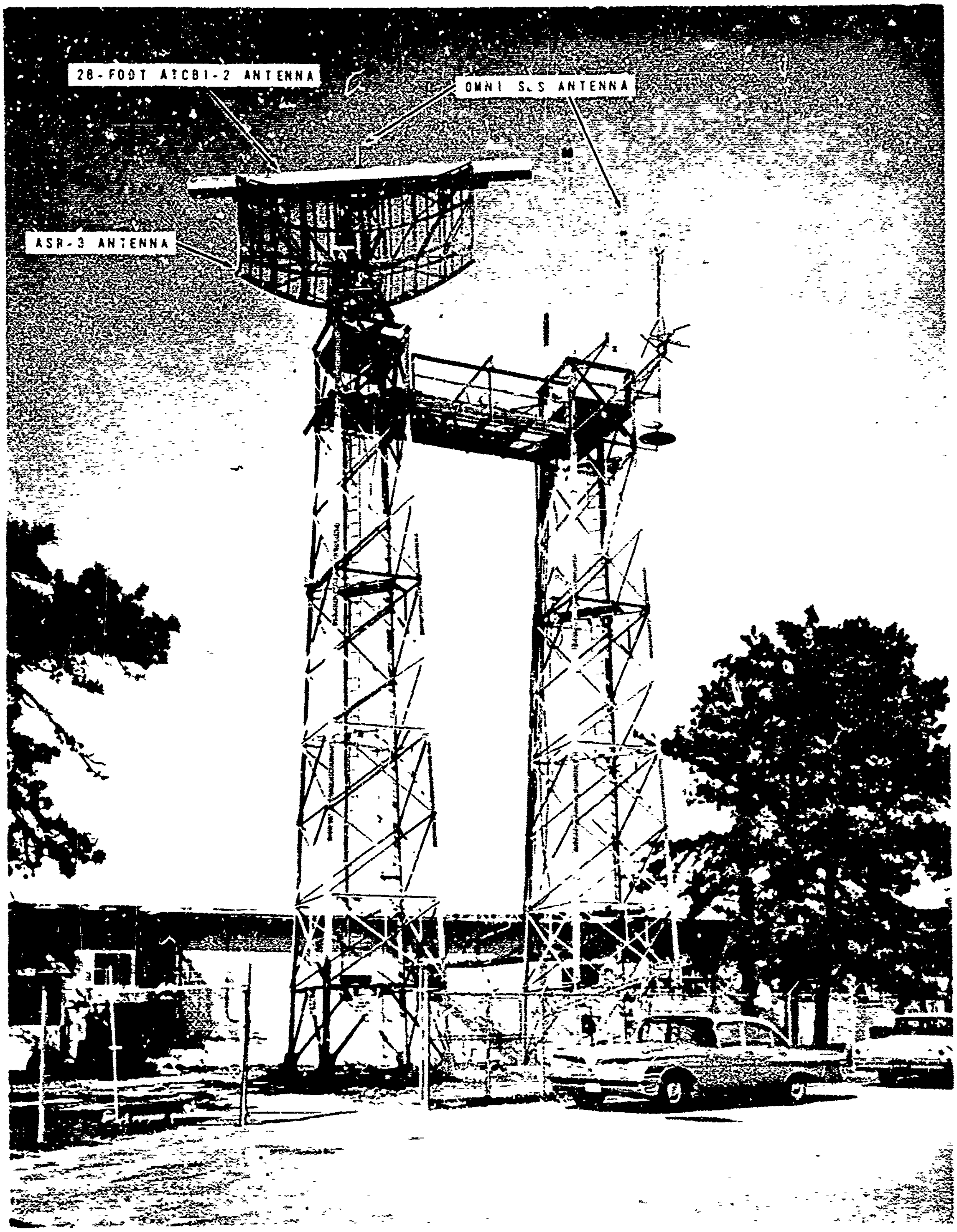

FIG. I-4 ATC RADAR BEACON SYSTEM ANTENNA INSTALLATION (NAFEC, BUILDING 14)

APPENDIX II

RESUME OF UAL/FAA RADAR BEACON ALTITUDE REPORTING FLIGHTS MONITORED

B-727

(Aircraft in cruise condition only with altitude confirmation, and correspondence is at reference to the ground beacon readout.)

DATE	FLT	AIR FRAME	DPTR	DSTN	ALTITUDE GROUND	ALTITUDE ACFT	HIGH (Alt. Correspondence)												LOW	
							600	500	400	300	200	100	0	100	200	300	400	500	600	% Error
9/1	U7227	Q	EWR	ORD	240	240							X							0.0
9/1	U7322	G	ORD	EWR	250	250							X							0.0
9/1	U7235	I	EWR	ORD	308	308							X							0.0
9/2	U7221		EWR	ORD	327	330				X										0.9
9/2	U7468	O	ORD	LGA	361	360								X						0.3
9/2	U7235	H	PHL	ORD	352	350									X					0.6
9/2	U7227	E	EWR	ORD	350	350							X							0.0
9/3	U7271	S	EWR	ORD	351	350								X						0.3
9/3	U7441	L	PHL	ORD	350	350							X							0.0
9/3	U7455	I	LGA	ORD	350	350							X							0.0
9/3	U7450	L	OR	PHL	250	250							X							0.0
9/3	U7235	L	PHL	ORD	199	200						X								0.5
9/4	U7411	B	PHL	ORD	352	350									X					0.6
9/4	U7322	L	ORD	EWR	330	330							X							0.0
9/4	U7271	E	EWR	ORD	350	350							X							0.0
9/4	U7472	J	ORD	EWR	220	220							X							0.0
9/4	U7235	B	PHL	ORD	352	350									X					0.6
9/8	U7235	L	PHL	ORD	291	290								X						0.3
9/8	U7455	F	LGA	ORD	350	350							X							0.0
9/9	U7401	O	LGA	ORD	275	280		X												2.0
9/9	U7271	H	EWR	ORD	352	350									X					0.6
9/9	U7441	M	PHL	ORD	346	350			X											1.0
9/9	U7472	O	ORD	LGA	265	270		X												2.0
9/9	U7227	C	EWR	ORD	282	280									X					0.7
9/10	U7227	E	EWR	ORD	319	310							X							0.0
9/10	U7420	F	CLE	LGA	194	195						X								0.5
9/10	U7221	J	PHL	ORD	223	224						X								0.4
9/10	U7455	F	LGA	ORD	350	350							X							0.0

DATE	FLT	AIR FRAME	DPTR	DSTN	ALTITUDE GROUND	ALTITUDE ACFT	HIGH (Alt. Correspondence)												LOW	
							600	500	400	300	200	100	0	100	200	300	400	500	600	% Error
9/11	U7441	N	PHL	ORD	277	280				X										1.0
9/11	U7271	M	EWR	ORD	353	350										X				0.8
9/11	U7335	S	LGA	ORD	282	280									X					0.7
9/11	U7455	H	LGA	ORD	313	310										X				0.9
9/11	U7322	S	ORD	EWR	333	330										X				0.9
9/11	U7472	T	ORD	LGA	329	330						X								0.3
9/11	U7235	N	PHL	ORD	345	350		X												1.0
9/14	U7457	T	LGA	ORD	355	350												X		1.0
9/14	U7468	E	ORD	LGA	329	330						X								0.3
9/14	U7235	H	PHL	ORD	242	240									X					0.8
9/14	U72.7	J	EWR	ORD	348	350					X									0.6
9/14	U7411	H	PHL	ORD	353	350										X				0.8
9/14	U7221	L	PHL	ORD	349	350						X								0.3
9/15	U7472	A	MDW	LGA	330	330							X							0.0
9/15	U7455	B	LGA	ORD	352	350									X					0.6
9/15	U7468	B	ORD	LGA	332	330									X					0.6
9/16	U7221	D	PHL	ORD	350	350							X							0.0
9/16	U7335	J	LGA	PHL	347	350				X										0.8
9/16	U7271	T	EWR	ORD	348	350					X									0.6
9/16	U7441	O	PHL	ORD	349	350						X								0.3
9/16	U7455	F	LGA	ORD	350	350							X							0.0
9/16	U7450	O	ORD	PHL	329	330						X								0.3
9/16	U7468	F	ORD	PHL	371	370								X						0.3
9/16	U7235	G	PHL	ORD	350	350							X							0.0
9/17	U7221	K	PHL	ORD	285	290		X												2.0
9/17	U7457	C	LGA	MDW	352	350									X					0.6
9/17	U7455	B	LGA	ORD	313	310										X				1.0
9/17	U7227	R	EWR	ORD	312	310									X					0.6
9/17	U7468	B	ORD	LGA	242	240									X					0.8
9/18	U7455	T	LGA	ORD	349	350						X								0.3
9/18	U7441	N	PHL	ORD	345	350		X												1.0
9/18	U7472	S	ORD	EWR	332	330									X					0.6
9/18	U7322	M	ORD	EWR	347	350				X										0.9
9/18	U7335	Q	LGA	MDW	309	310						X								0.3

DATE	FLT	AIR FRAME	DPTR	DSTN	ALTITUDE GROUND	ACFT	HIGH (Alt Correspondence) LOW													% Error
							600	500	400	300	200	100	0	100	200	300	400	500	600	
9/21	U7221	R	PHL	ORD	313	310										X				1.0
9/21	U7322	C	ORD	EWR	191	190								X						0.5
9/21	U7227	C	EWR	ORD	262	260									X					0.8
9/21	U7455	E	LGA	ORD	349	350						X								0.3
9/21	U7468	E	ORD	LGA	329	330						X								0.3
9/21	U7335	O	LGA	CLE	310	310							X							0.0
9/22	U7457	C	PHL	ORD	281	280								X						0.3
9/22	U7271	K	EWR	ORD	356	350													X	2.0
9/22	U7455	G	LGA	ORD	350	350							X							0.0
9/22	U7472	U	ORD	LGA	331	330								X						0.3
9/22	U7221	J	PHL	ORD	309	310						X								0.3
9/22	U7227	M	EWR	ORD	346	350					X									0.6
9/23	U7472	O	MDW	LGA	291	290								X						0.3
9/23	U7457	O	LGA	MDW	350	350							X							0.0
9/23	U7441	F	PHL	ORD	351	350								X						0.3
9/23	U7235	F	PHL	ORD	281	280								X						0.3
9/23	U7468	B	ORD	LGA	33[illegible]	330								X						0.3
9/23	U7455	B	LGA	ORD	352	350									X					0.6
9/24	U7227	P	EWR	ORD	304	310	X													2.0
9/24	U7441	M	PHL	ORD	347	350				X										0.8
9/24	U7221	L	PHL	ORD	350	350							X							0.0
9/24	U7455	K	LGA	ORD	306	300													X	2.0
9/24	U7468	K	MDW	LGA	336	330													X	2.0
9/24	U7235	M	PHL	ORD	346	350			X											1.0
9/24	U7322	P	ORD	EWR	325	330		X												1.0
9/25	U7457	Q	LGA	ORD	345	350					X									0.6
9/25	U7472	Q	MDW	LGA	328	330					X									0.6
9/25	U7335	O	LGA	CLE	241	240								X						0.4
9/25	U7411	H	PHL	ORD	311	310								X						0.3
9/25	U7455	J	LGA	ORD	348	350					X									0.6
9/25	U7322	E	ORD	EWR	260	260							X							0.0
9/25	U7227	E	EWR	ORD	348	350					X									0.6

DATE	FLT.	AIR FRAME	DPTR	DSTN	ALTITUDE GROUND	ACFT	HIGH (Alt Correspondence) LOW													% Error
							600	500	400	300	200	100	0	100	200	300	400	500	600	
9/28	U7441	P	PHL	ORD	346	350			X											1.0
9/28	U7335	X	LGA	CLE	350	350							X							0.0
9/28	U7221	C	PHL	ORD	354	350											X			1.0
9/28	U7455	F	LGA	ORD	351	350								X						0.3
9/28	U7472	E	MDW	LGA	345	350					X									0.6
9/28	U7322	R	ORD	EWR	278	275										X				1.0
9/29	U7221	E	PHL	ORD	309	310						X								0.3
9/29	U7018	Q	Ferry Flt		329	330						X								0.3
9/29	U7441	Q	PHL	ORD	309	310						X								0.3
9/29	U7455	K	LGA	ORD	316	310													X	2.0
9/29	U7227	Q	EWR	ORD	349	350						X								0.3
9/30	U7271	R	EWR	ORD	352	350									X					0.6
9/30	U7457	O	LGA	MDW	351	350								X						0.3
9/30	U7441	J	PHL	ORD	349	350						X								0.3
9/30	U7455	C	LGA	ORD	353	350										X				0.8
9/30	U7227	V	EWR	ORD	352	350									X					0.6
9/30	U7472	O	MDW	LGA	245	245							X							0.0
9/30	U7468	C	ORD	LGA	333	330										X				0.9
9/30	U7221	K	PHL	ORD	356	350													X	2.0
9/30	U7335	K	EWR	CLE	350	350							X							0.0
10/1	U7457	X	LGA	MDW	349	350						X								0.3
10/1	U7441	Q	PHL	ORD	309	310						X								0.3
10/1	U7235	Q	PHL	ORD	348	350					X									0.3
10/1	U7227	F	EWR	ORD	351	350								X						0.3
10/1	U745[illegible]	Q	EWR	ORD	179	180						X								0.5
10/2	U7227	I	EWR	ORD	340	340							X							0.0
10/2	U7468	E	ORD	LGA	329	330						X								0.3
10/2	U7235	Y	PHL	ORD	352	350									X					0.6
10/2	U7472	X	MDW	LGA	331	330								X						0.3
10/2	U7221	O	PHL	ORD	390	390							X							0.0
10/2	U7271	L	EWR	ORD	349	350						X								0.3
10/2	U7335	R	PHL	ORD	354	350											X			1.0
10/2	U7322	I	ORD	EWR	329	330						X								0.3
10/2	U7455	E	LGA	ORD	349	350						X								0.3
10/2	U7441	V	PHL	ORD	352	350									X					0.6

DATE	FLT	AIR FRAME	DPTR	DSTN	ALTITUDE GROUND	ALTITUDE ACFT	HIGH (Alt Correspondence) 600	500	400	300	200	100	0	100	200	300	400	500	LOW 600	% Error
10/5	U7401	Q	LGA	CHI	350	350							X							0.0
10/5	U7235	H	PHL	ORD	241	240								X						0.4
10/5	U7168	P	ORD	LGA	326	330			X											1.0
10/5	U7421	M	EWR	CLE	261	260								X						0.4
10/5	U7227	G	EWR	ORD	310	310							X							0.0
10/5	U7472	O	LGA	MDW	372	370									X					0.5
10/5	U7455	P	LGA	ORD	345	350		X												1.0
10/5	U7441	H	PHL	ORD	351	350								X						0.3
10/5	U7271	M	EWR	ORD	307	310				X										1.0
10/6	U7441	N	PHL	ORD	310	310							X							0.0
10/6	U7235	N	PHL	ORD	310	310							X							0.0
10/6	U7468	O	ORD	LGA	310	310							X							0.0
10/6	U7227	F	EWR	ORD	351	350								X						0.3
10/6	U7455	O	LGA	ORD	309	310						X								0.3
10/6	U7221	U	PHL	ORD	[illegible]	310									X					0.6
10/6	U7335	R	LGA	CLE	353	350										X				0.8
10/7	U7335	Y	LGA	CLE	312	310									X					0.6
10/7	U7450	C	ORD	PHL	183	180										X				2.0
10/7	U7441	C	PHL	ORD	314	310											X			1.0
10/7	U7221	G	PHL	ORD	351	350								X						0.3
10/7	U7455	E	LGA	ORD	309	310						X								0.3
10/7	U7472	Q	MDW	LGA	328	330					X									0.6
10/7	U7457	M	LGA	ORD	388	390					X									0.5
10/7	U7227	M	EWR	ORD	259	260						X								0.4
10/8	U7335	R	LGA	CLE	351	350								X						0.3
10/8	U7441	J	PHL	ORD	308	310					X									0.6
10/8	U7235	J	PHL	ORD	347	350				X										0.8
10/8	U7227	P	EWR	ORD	345	350		X												1.0
10/13	U7441	E	PHL	ORD	350	350							X							0.0
10/13	U7468	J	ORD	LGA	328	330					X									0.6
10/13	U7235	O	PHL	ORD	348	350					X									0.6
10/13	U7271	F	LGA	ORD	251	250								X						0.4
10/13	U7455	J	LGA	ORD	347	350				X										0.8
10/13	U7472	K	MDW	LGA	370	370							X							0.0
10/13	U7450	E	ORD	PHL	250	250							X							0.0
10/13	U7335	N	LGA	CLE	350	350							X							0.0

DATE	FLT	AIR FRAME	DPTR	DSTN	ALTITUDE GROUND	ALTITUDE ACFT	HIGH (Alt Correspondence) 600	500	400	300	200	100	0	100	200	300	400	500	LOW 600	% Error
10/14	U7221	F	PHL	ORD	241	240								X						0.4
10/14	U7457	N	LGA	ORD	350	350							X							0.0
10/14	U7335	P	LGA	CLE	313	310										X				1.0
10/14	U7227	W	EWR	ORD	309	310						X								0.3
10/14	U7235	J	PHL	ORD	269	270						X								0.4
10/14	U7420	Q	CLE	LGA	270	270							X							0.0
10/14	U7468	Q	ORD	LGA	329	330						X								0.3
10/14	U7450	J	ORD	PHL	230	230							X							0.0
10/14	U7455	Q	LGA	ORD	280	280							X							0.0
10/14	U7322	W	ORD	EWR	329	330						X								0.3
10/15	U7468	L	ORD	LGA	251	250								X						0.4
10/15	U7455	L	LGA	ORD	351	350								X						0.3
10/15	U7227	K	EWR	ORD	380	380							X							0.0
10/15	U7322	K	ORD	LGA	240	240							X							0.0
10/15	U7455	L	LGA	ORD	350	350							X							0.0
10/16	U7221	M	PHL	ORD	287	290				X										1.0
10/16	U7457	P	LGA	ORD	384	390	X													2.0
10/16	U7235	E	PHL	ORD	310	310							X							0.0
10/16	U7455	F	LGA	ORD	281	280								X						0.4
10/16	U7271	C	EWR	ORD	344	340											X			1.0
10/16	U7227	I	EWR	ORD	351	350								X						0.3
TOTALS	186	25					2	8	4	9	14	32	41	29	22	12	4	1	5	

Legend

FLT - United Airlines Flight Number
FRAME - United Airlines Airframe Number
DPTR - Airport Departure or Origin of Flight
DSTN - Airport Destination or Terminus of Flight
GROUND - Altitude as Read Out on the Ground ATC Radar Beacon
ACFT - Altitude as Reported by Pilot from the Flight Instrument

HIGH - Indicated that the pilot reported altitude was higher than the ATC Radar Beacon altitude report
LOW - Indicated that the pilot reported altitude was lower than the ATC Radar Beacon altitude report

CLE - Cleveland-Hopkins Airport
EWR - Newark Airport
LGA - La Guardia Airport
MDW - Chicago Midway Airport
ORD - Chicago-O'Hare International Airport
PHL - Philadelphia International Airport

APPENDIX III

B-727 EQUIPMENT REPLACEMENT DURING AUTOMATIC ALTITUDE REPORTING PROGRAM

9/1/64 to 10/17/64

1. LITTON AIR DATA COMPUTERS

Airframe	Date(s) Replaced
B	9/23
D	9/4
H	9/18
I	9/18, 9/20
K	10/3
N	9/30
O	9/15
T	9/29

2. ATC TRANSPONDERS

Airframe	Date(s) Replaced
A	10/7
C	9/23
D	9/4, 9/4, 9/11, 9/12, 9/14
G	10/1, 10/1
H	10/15
I	10/6
J	10/11
K	9/9
Q	9/19, 9/25, 9/30, 10/1
R	9/2, 9/30, 9/29, 9/29
W	10/9, 10/9

Federal Aviation Agency, Systems Research and Development Service, National Aviation Facilities Experimental Center, Experimentation Division, Atlantic City, N. J. UAL/FAA ATC RADAR BEACON ALTITUDE REPORTING TEST by Felix F Hierbaum, Jr, and Carlo Yulo, Final Report, January 1965, 24 pp, incl illus plus 3 apps (Project No 242-006-03X, Report No. RD-65-10)

Unclassified Report

The National Aviation Facilities Experimental Center monitored 186 flights of 25 different United Air Lines Boeing 727 aircraft and 17 flights of three different Douglas DC-8F aircraft, all equipped with Air Traffic Control Radar Beacon System (ATCRBS) automatic altitude reporting capability

The participating aircraft were equipped with two different types of automatic altitude reporting configurations, and two different types of ground decoding and display systems were used Information was gathered on adequacy of the ATCRBS pressure altitude transmission medium, the (over)

UNCLASSIFIED

I. Hierbaum, Felix F. Jr
Yulo, Carlo
II. Proj. No 242-006-03X
III. Report No RD-65-10

Descriptors

ATC Systems
Civil Aviation
Altimeters
Altitude Encoders
Radar Beacons
Radar Transponders
Numeric Display
Aircraft Equipment
Air Data Computers

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technical integrity of the two specific decoding and display systems, and correspondence between the pilot altitude display in the cockpit and the radar beacon altitude display at the ground facility.

The data analyzed and controller comments on data received are included along with review notes.

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